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APRIL 1993

LASER CUTTING OF STRUCTURAL MEMBERS WITH HIGH POWERED ND:YAG USER SYSTEM

Project Report For The

SP-7 PANEL OF THE

SHIP PRODUCTION COMMITTEE OF THE

NATIONAL SHIPBUILDING RESEARCH PROGRAM

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Applied Research Laboratory

Laser Cutting of Structural Members with High Powered Nd:YAG Laser System Panel SP-7 Project Report

E. J. Whitney
P. E. Denney

Technical Memorandum
File No. 93-022
19 February 1993

Copy No. ________

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ABSTRACT

The application of laser technology for cutting structural members used in ship building was investigated. The original program required the use of a 1.8 kW Nd:YAG CW laser. This was expanded to include a 2.4 kW Nd:YAG CW laser, as well as a 1.4 and 14 kW $C0_2$ CW lasers. Process parameters such as laser power, travel speed, cutting gas type and flow, and focusing optic were adjusted to determine the feasibility of each laser for cutting structural members. Results indicated that all lasers, except the 1.8 kW Nd:YAG laser, produced acceptable cuts at speeds greater than 20 IPM. However, each laser is functionally different and careful evaluation of an application (s) is required in order to determine the most suitable laser. For example, to process large structural members with a CO_2 laser, a complex beam manipulation device is required. Processing the same members with a Nd:YAG laser requires fiber optic delivery. Both types of systems are commercially available.

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FORWARD

The project presents the results of an R&D project initiated by members of the Society of Naval Architects and Marine Engineers Ship Production Committee, Panel SP-7.

The project was conducted by the Applied Research Laboratory of The Pennsylvania State University (ARL Penn State), State College, Pennsylvania and by Bath Iron Works, Bath, Maine. The project was conducted by Paul Denney and Eric Whitney both of ARL Penn State This report was prepared by Eric Whimey. Mr. Paul Blomquist of Bath iron Works made significant technical contributions. The SP-7 panel chairman is Mr. Lee Kvidahl and the Program Manager is Mr. O. J. Davis, both of Ingalls Shipbuilding, Inc. The NSRP Administrator is Virgil Rinehart, Maritime Administration of the Department of Transportation.

A Word About the NSRP:

The National Shipbuilding Research Program (NSRP) has been engaged in research related to improvements in shipbuilding in the U. S. since 1973. The program is a cooperative effort involving commercial and U. S. Naval shipyards and related agencies, industries, educational and research institutions.

Since the inception of the program in 1973 R&D projects have been performed with significant contributions in the areas of facilities, environmental effects, outfitting and production aids, design and production integration, human resource innovation, shipbuilding standards, welding, industrial engineering, education and training, flexible automation and surface preparation and coatings. A library and bibliography of NSRP reports is maintained at the University of Michigan, Transportation Research Institute, Ann Arbor, Michigan.

The program is funded by cooperative agreement contracts by the U. S. Navy and the Maritime Administration of the U. S. Department of Transportation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BACKGROUND

Cutting structural steel members for ships has historically been a time consuming, labor intensive process. Plasma arc, oxy-fuel and manual circular saws are all used to cut the various shapes. Plasma arc is preferred because of its cutting speed and the high quality of the cuts. Recent advances in high power Nd:YAG lasers coupled with fiber optic delivery systems have the potential for significantly reducing the cost of preparing structural steel members for assembly. Laser cutting can produce higher quality cuts with speeds equaling or exceeding plasma processes. In addition, laser cutting produces less fumes and less material waste e.g., both sides of a laser cut are of equal quality. Laser processes are typically easier to-automate than plasma arc because there is no high frequency EMF to interfere with CNC and other electronic equipment.

Summary of Laser Cutting Technology

There are two types of lasers typically used for laser cutting applications. The most common type is the fast axial flow CO_2 with pulsing capability. The second type is the Nd:YAG laser. This type of laser has, until recently, been of little use in laser cutting applications because of power limitations. Recently developed Nd:YAG lasers in the multi-kilowatt range have been developed and are being rapidly integrated into manufacturing applications requiring-cutting.

$C0_2$ Laser Cutting

CO, lasers are widely used to blank sheet metal and to cut thick section material. There are a number of different ties of CO2 lasers used. The important operating characteristics of CO_2 lasers can be summarized as follows:

- Mode of Operation: Pulsed, CW, or Both
- Type of Pulsing: Enhanced or Unenhanced
- Type of Gas Flow: Slow Axial, Fast Axial, or Transverse
- Mode of Beam and Polarization
- Maximum Average Power Output of Laser

The current state-of-the-art in CO_2 laser cutting is the RF excited fast axial flow lasers that are capable of pulsing in the 1 kHz range with peak pulse power 4- 8 times the average power. Maximum average power output for an RF excited laser is currently about 6 kw. For example, a 3 kw CO_2 laser operating at 2.2 kw capable of enhanced pulse operation can cut 0.75 in. mild steel at 30 IPM with a kerf width of less than .02 in.

High power lasers are typically defined as lasers operating above 8 kw. These lasers are typically transverse flow and operated with a high order beam. In addition, these lasers can not use transmissive optics. High power lasers can be effective cutting lasers. A 25 kw CO_2 laser is capable of cutting 2.125 in. thick steel at 5 inches per minute.

In general, a 6 kw enhanced pulsed laser can produce superior quality cuts to the 25 kW laser at the same material, thickness, and speed.

Nd:YAG Laser Cutting

Nd:YAG lasers have long been used for drilling and small welding applications. These lasers have been, until recently, limited to about 400 W maximum average power output. However, in the pulse mode, very high peak powers can be achieved. A significant drawback of these lasers has been that the pulse rate is typically less than 200 Hz. This rate is too slow for cost effective cutting. Also, the 400 W maximum power limited the thickness of material capable of being cut to approximately 0.125 inches.

Recently, Nd:YAG lasers in the 1 -2+ kW range have become commercially available. These lasers are able to compete economically with established CO_2 cutting systems. For many applications the Nd:YAG based systems maybe more cost effective and versatile than a comparable CO_2 based system. The primary advantage of the Nd:YAG system is the ability of the laser to be delivered to the work piece via an optical fiber. This offers flexibility and lowers cost, especially for large thick section applications that are not easily manipulated by CNC type equipment.

Comparison Between Plasma Cutting and Laser Cutting Systems

Plasma cutting is a widely used process and is capable of producing high quality economical cuts. However, there are some disadvantages in plasma cutting:

- Only one side of the cut is typically usable, this requires additional cuts to produce acceptable edges.
- Plasma cutting often generates large amounts of waste gas, causing environmental concerns.
- High frequency starts can cause EMF interference, making automation problematic.
- Potentially excessive heat affected zones.

Laser cutting does not suffer from the above disadvantages. However, plasma cutting is likely to be substantially faster when cutting highly reflective materials such as aluminum and its alloys.

EXPERIMENTAL PROCEDURE AND RESULTS

The suitability of using both Nd:YAG and CO_2 lasers for cutting typical ship structural members was investigated. The 1.5kW CO_2 laser was an EFA51 fast axial flow laser manufactured by Coherent General Inc. This laser is capable of pulse and CW operation. The maximum pulse repetition rate is 2kHz, the pulse is not enhanced. Part movement is accomplished using Klinger precision tables and controller. The 14kW CO_2 is a United Technologies SM21. Beam movement is accomplished using the Laser Maculating Robotic System (IAN). LARS has six degree-of-freedom. The Nd:YAG lasers were a Hobart (formerly Marteck) MM1800 1.8 kW CW and an MM2400 2.4kW CW laser both fiber optic delivery. The fiber was manipulated with an Automatix A132 robot. The Nd:YAG laser, A132 Robot, and other process functions are controlled by a PC using software developed by ARL Penn State. The software has an automatic run documentation routing that provides a hard copy of the parameter settings for each run and provides for operator comment. Appendix A contains an example of the software output.

1.8 kW Nd:YAG Laser Cutting

initial trials were made using f4 focusing optics. These optics are specifically designed for cladding operations and as a consequence of this design criteria, the spot power density at focus for this device is not sufficient to induce a key hole. This means that penetration is conduction limited. In the intitial stages of cutting, a weld pool is formed. The assist gas then blows the molten metal from the laser interaction area and penetration is achieved by continuously blowing metal from the interaction area as it is melted. Once full penetration is achieved, cutting is continued by blowing metal from the weld front. Since little or no metal is vaporized, all the metal must be removed by the assist gas.

Figure 1 shows the results of trials made on 0.060 in. thick 304 SS. Samples 10-1-92-1, 2, and 3 show incomplete penetration at speeds of 100,80, and 60 inches per minute. Sample 10-1 -92-4 shows that a through cut was achieved at 40 inches per minute.

Figure 2 shows a similar series of tests on 0.125 in. cold rolled steel. Samples 10-1-92-5, 6, 7, and 8 were done at 80, 60, 40, and 20 inches per minute. Through penetration was not achieved. Laser power was at maximum (approximately 1500W at the work piece), focus was at the surface of the piece, and 160 PSI oxygen was used as the cutting gas.

Figure 3 shows a through cut made on 0.437 in. thick HSLA steel. The cutting speed was 1 inch per minute. Laser power was at maximum (approximately 1500W at the work piece), focus was at the surface of the piece, and 160 PSI oxygen was used as the cutting gas. Note the heavy dross present on the back side of the cut. This dross is a result of the conduction mode of the cut.

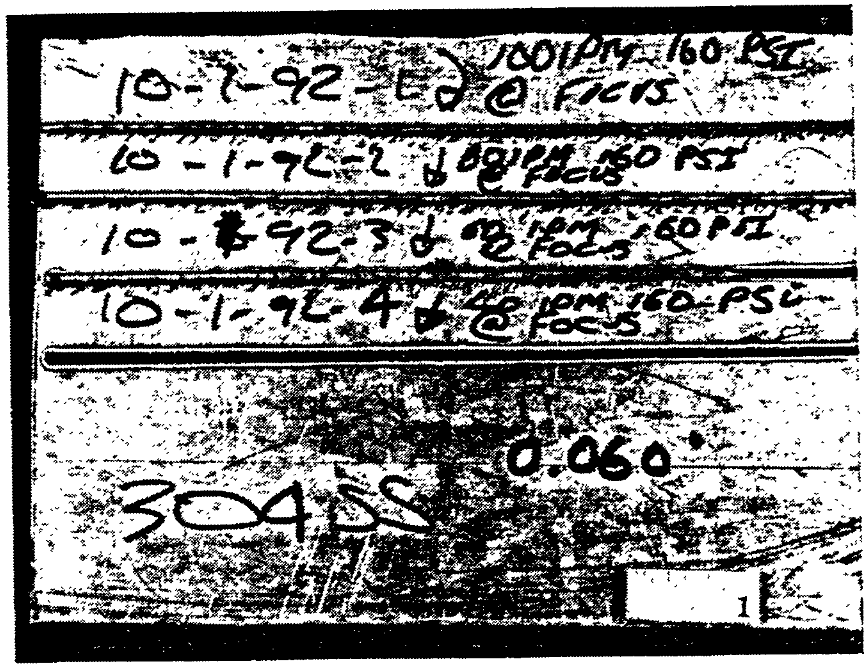


FIGURE 1. 304SS 0.06 in. Thick Samples 10-1-92-1, 2, 3

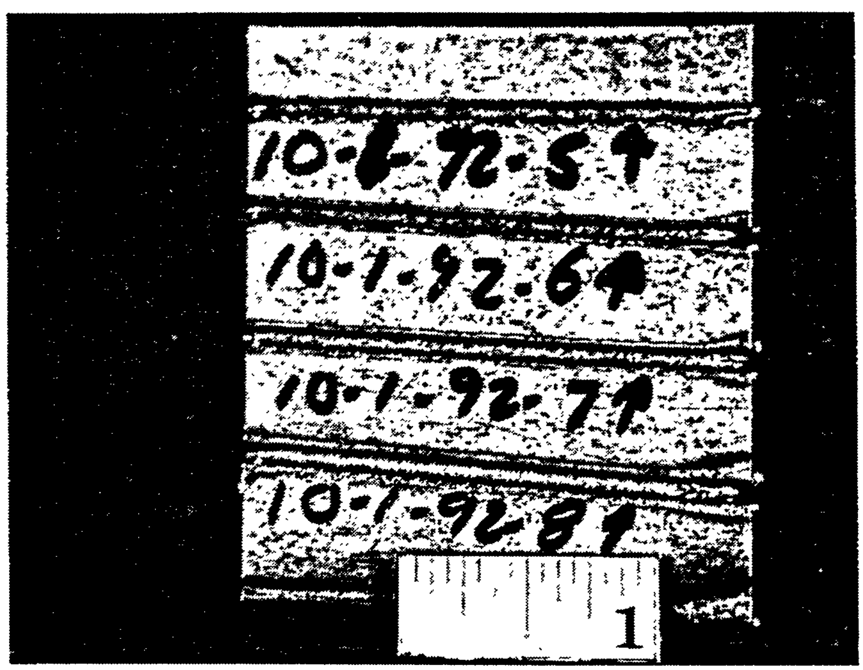


FIGURE 2. Cold Rolled Steel 0.125 in. Thick Samples 10-1-92-5, 6, 7, 8

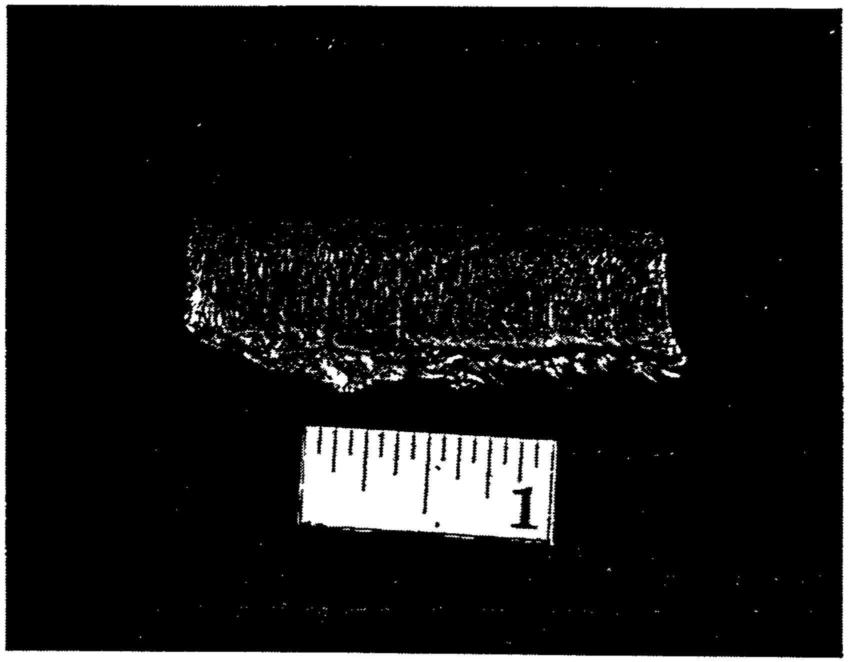


FIGURE 3. HSLA Steel 0.437 in. Thick

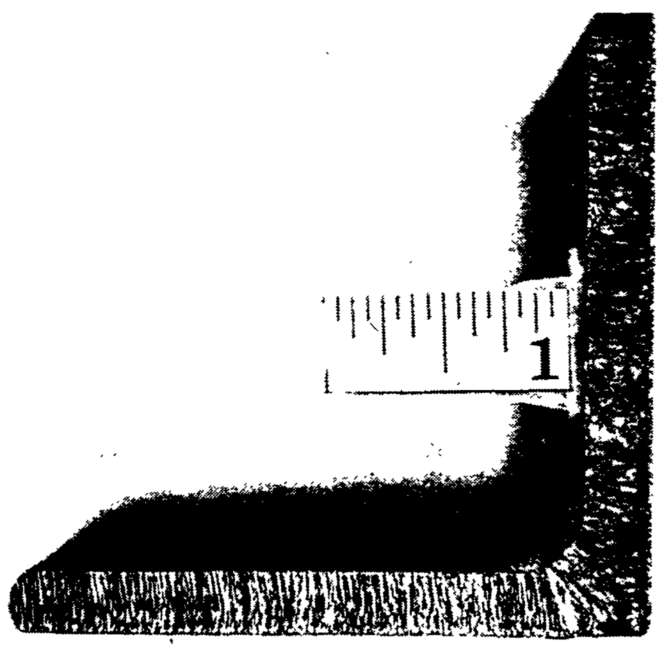


FIGURE 4. Structural Steel 0.25 in. Thick

In summary, cutting trials were performed on a variety of materials. However, to maximize the speed of the cutting, the power level was set at 1800W and the cutting assist gas pressure was se at 160 PSI, the maximum possible for the present gas delivery system. Cutting speed was adjustec to identify the maximum possible cutting speed. Table 1 lists the final parameters for each material.

TABLE 1. Maximum Cutting Speed for Various Materials and Thicknesses

MATERIAL	THICKNESS (in.)	CUTTING SPEED (IPM)
304ss	0.060	4 0
NAPAC 80	0.087	30
COLD ROLLLED SHEET	0.063	40
COLD ROLLED FLAT	0.250	3
HSLA 80	0.459	1

All through cuts exhibited a significant amount of dross on the back side of the cut. The kerf was measured at 0.044-0.057 in.

1.8 kW Nd:YAG Cutting with f2 Optics

In reviewing the results of cuts made using the f2 optic, it became apparent that to achieve satisfactory cuts, the spot power density of the laser needed to be increased. ARL Penn State acquired an fl focusing head for the Nd:YAG laser. This set of optics increases spot power density 4X over the f4 optics. Cutting trials were made on structural steel members.

The power level for the trials using the f4 optics was set at maximum and focus was always set a the surface of the work piece. The angle of the beam was fixed at 15° from the normal to the surface. This angle was established to prevent back reflections from damaging the fiber.

The parameters that were varied during process development included travel speed and cutting gas pressure and flow. It was determined that reducing gas flow required a reduction in travel speec to achieve a through cut. However, very high gas flow rates (> 200CFH) reduced cut quality by increasing gouging of the cut surface.

TABLE 2. 1.8 kW Nd:YAG Laser (f2 Optic) Cutting Parameters

PARAMETER	VALUE
LASER POWER	1800W
FOCUS	@ SURFACE
ANGLE TO NORMAL	15°
GAST TYPE	OXYGEN
GAS PRESSURE	160 PSI
GAS FLOW	180 CFM
TRAVEL SPEED	3 IPM
MATERIAL TYPE	STRUCTURAL STEEL
THICKNESS	0.25 in.

2.4 kW Nd:YAG Cutting with High Pressure f2 Optic

ARL Penn State received a Hobart 2.4 kW CW Nd:YAG laser in December 1992. A number of cutting trials on various materials was performed on this laser. The process parameters that were held constant during all trials are give in Table 3.

TABLE 3. Constant Parameters

PARAMETER	VALUE
ASSIST GAS TYPE	OXYGEN
ASSIST GAS FLOW	150 CFH
ASSIST GAS PRESSURE	140 PSI
NOZZLE STAND OFF	0.025 in.
FOCUS	@ SURFACE
ANGLE TO NORMAL	w

The first series of experiments was performed on 0.090 in. thick HSLA sheet. The experimental matrix and qualitative results are shown in Table 4.

TABLE 4. 2.4 kW Nd:YAG Cutting of 0.09 in. HSLA

SAMPLE NO.	LASER POWER (WATTS)	TRAVEL SPEED (IPM)	RESULTS
2-1-93-1	1000	80	ROUGH CUT
2-1-93-2	1000	120	BETTER, DROSS
2-1-93-3	1000	100	DROSS
2-1-93-4	2000	100	LESS DROSS
2-1-93-5	2400	100	SAME AS -4
2-1-93-6	2000	100	SAME AS -4
2-1-93-7	2000	200	DROSS BRIDGE
2-1-93-8	2400	200	GOOD CUT

Figure 5 shows is a photomacrograph of samples 2-1-93-1 and 2-1-93-3.

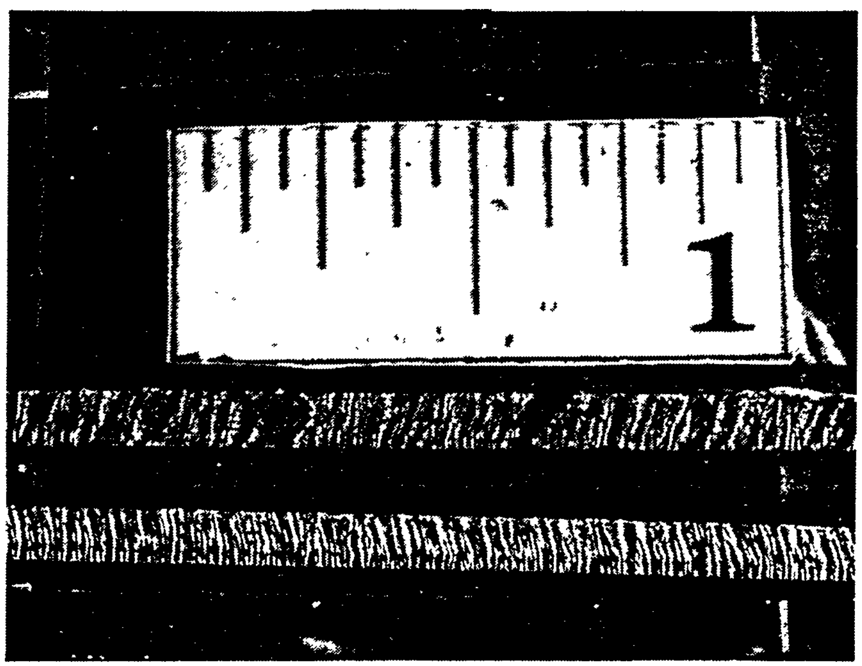


FIGURE 5. Samples 2-1-93-1 (Top) and 2-1-93-3 (Bottom)

A second series of cutting trials was performed on 0.25 in. thick carbon steel. Table 5 shows the experimental matrix and qualitative results.

TABLE 5. 2.4 kW Nd:YAG Cutting of 0.25 in. Carbon Steel

SAMPLE NO. i	LASER POWER (WATTS)	TRAVEL SPEED (IPM)	RESULTS
2-1-93-9	2400	60	RAGGED CUT
2-1-93-10	2400	80	GOOD CUT
2-1-93-11	2440	100	DROSS BRIDGE
2-1-93-12	2430	40	RAGGED CUT
2-1-93-13	2435	60	OUT OF FOCUS
2-1-93-14	2430	60	RAGGED CUT

Figure 6 is a photomacrograph of samples 2-1-93-10 and 2-1-93-12.

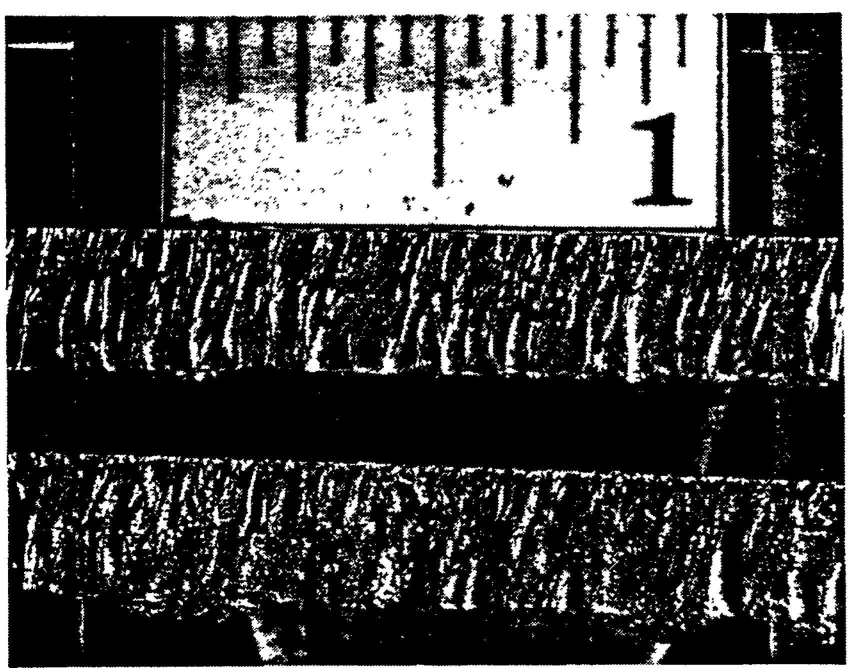


FIGURE 6. Samples 2-1-93-10 (Top) and 2-1-93-14 (Bottom)

Finally, several trials were made simulating a stripping operation. The goal of the trials was to strip as close to the web of the I-beam as possible while maintaining good cut quality. Using the parameters developed for the 0.25 in. thick material as a base line, cuts were made in the fillet region at 40 IPM for about 2 in. along the length of the beam, then the robot moved outward at 80 IPM to cut an “L” shape. Figure 7 is a photomacrograph of the cut surface in the fillet.

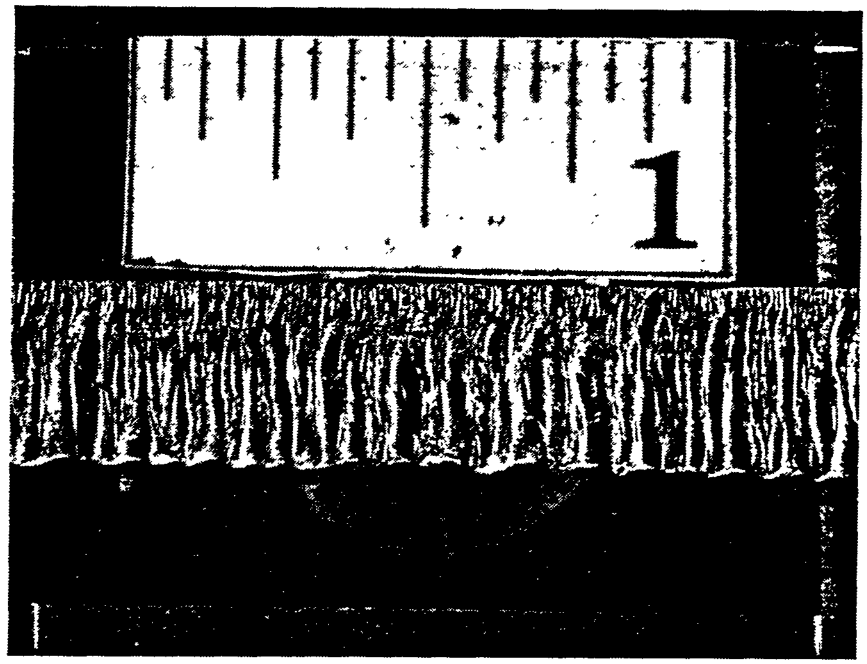


FIGURE 7. Simulated Stripping Operation, 2-2-93-2

No shapes (such as drain holes) were cut using the 2.4 kW Nd:YAG laser, however, these could readily be cut using this laser.

14 kW CO_2 Cutting

A number of I-beams were supplied by Bath Iron Works for stripping trials. Prior to stripping actual I-beams several trial cuts were made to identify an initial set of cutting parameters. The cutting gas nozzle was positioned 0.04 in. from the beam (trailing) and 0.25 in. off the work piece for all trials. Table 6 shows the experimental matrix and qualitative results.

TABLE 6. Experimental Matrix for 14 kW CO_2 Laser

SAMPLE NO.	LASER POWER (kW)	TRAVEL SPEED (IPM)	CUTTING GAS TYPE	GAS PRESSURE (PSI)	RESULTS
11-20-92-1	9.5	60	N_z	700	PARTIAL
11-20-92-2	10	30	N_z	700	PARTIAL
11-20-92-3	10	15	AIR	700	THRU CUT
11-20-92-4	10	15	AIR	700	THRU CUT
11-20-92-5	10	30	AIR	700	THRU CUT
11-20-92-6	10	60	AIR	700	PARTIAL
11-20-92-7	10	50	AIR	700	PARTIAL
11-20-92-8	10	45	AIR	700	PARTIAL
11-20-92-9	10	40	AIR	700	THRU CUT

Additional trials were made (samples 11-23-92-1 to 11-23-92-1 1) on test pieces prior to cutting I-beams. Once a suitable set of parameters was established, four I-beams were processed (samples 11-23-92-12 to 11-24-92-5). Table 7 shows the series of stripping trials performed.

TABLE 7. EXPERIMENTAL MATRIX FOR 14 kW CO_2 LASER

SAMPLE NO.	LASER POWER (kW)	TRAVEL SPEED (IPM)	CUTTING GAS TYPE	GAS PRESSURE (PSI)	RESULTS*
11-23-92-1	9.4	30	AIR	500	T, D
11-23-92-2	9.5	20	AIR	500	T, D
11-23-92-3	9.5	20	AIR	700	T, D
11-23-92-4	9.7	15	AIR	700	T,D
11-23-92-5	9.7	20	AIR	700	T, D
11-23-92-6	9.6	15	AIR	700	T, D
11-23-92-7	9.6	20	AIRfO_2	70095	G
11-23-92-8	9.5	30	AIR/O_2	700/95	G
11-23-92-9	9.5	30	02-	95	P
11-23-92-10	9.5	40	02	95	P
11-23-92-11	9.5	30	AIR/O_2	700/95	G
11-23-92-12	9.5	3 0	AIR/O_2	700/95	G
11-23-92-13	9.5	30	AIR/O_2	700/95	ABORT
11-24-92-1	9.5	30	AIR/O_2	700/95	M
11-24-92-2	9 . 5	30	AIR/O_2	700/95	G
11-24-92-3	9.5	30	AIR/O_2	700/95	P
11-24-92-4	9.5	30	AIR/0_2	700/95	P
11-24-92-5	9.6	30	AIR/O_2	700/95	G

* T - through cut, D - dross present, G - good" cut, P - poor cut, M - misaligned path/partial cu

Photomacrographs of cut surfaces are contained in Appendix B and are explained in the lett report by Mr. Paul Blomquist. Additional documentation is contained in the video tape th accompanies this report.

1.5 kW $C0_2$ Cutting

Cutting trials were performed on the same structural steel as mentioned above. The parameters were chosen to maximize the speed of the cut while maintaining an acceptable cut. Table 8 contains the final parameters.

TABLE 8. 1.5 kW CO_z Laser Parameters

PARAMETER	VALUE
LASER POWER	1500W
FOCUS	@ SURFACE
ANGLE TO NORMAL	0^o
GAST TYPE	OXYGEN
GAS PRESSURE	160 PSI
GAS FLOW	180 CFM
TRAVEL SPEED	71 IPM
MATERIAL TYPE	STRUCTURAL STEEL
THICKNESS	0.25 in.

Photomacrographs of cut surfaces are contained in Appendix B and are explained in the letter report by Mr. Paul Blomquist. Additional documentation is contained in the video tape that accompanies this report.

VIDEO TAPE DOCUMENTATION

A video tape of laser processing of structural members showing the 1.5 kW and 14 kW CO_z laser and the 2.4 kW Nd:YAG laser was made under this contract. Due to time constraints regardin the shipping/delivery of the 1.8 kW Nd:YAG laser, a video tape of this laser was not made.Th video tape details all aspects of the laser operation.

CONCLUSIONS

The following conclusions can be made:

- Both the Nd:YAG and the CO_z lasers can produce superior quality cuts at speed comparable or better than plasma cutting.
- .Spot power density is an important consideration when developing a cutting process.

RECOMMENDATIONS

The following are recommendations for additional work

- . A detailed comparison including a cost-benefit analysis should be done comparing th implementation cost of a Nd:YAG and a CO_z based cutting system.
- . Cutting work should be done on structural aluminum members to determine th applicability of laser cutting on these alloys.
- Cut quality should be quantified in terms of heat affected zone, kerf width, recast laye dross.

ACKNOWLEDGMENTS

The following individuals are acknowledged for their contributions to this program. Mr. James McDermott for modifying the Nd:YAG control software as required, Mr. William Rhoads for operating the 14 kW $C0_2$ laser, Mr. Russ Knee for operating the Nd:YAG lasers, and Mr. Jay Tressler for operating the 1.5 kW CO_2 laser. The efforts of Mr. Dave Smith are acknowledged for his work in taking the photomacrographs. Also, Mike Coslo is acknowledged for his work in making the video tape of the various processes.

Mr. Paul Blomquist of Bath Iron Works is also acknowledged for his expert guidance of the stripping operation on the 14 kW CO_2 laser.

APPENDIX A

Nd:YAG LASER RUN SHEETS

10:38:08	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-13	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	160360 cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1685	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename	PGM1	Standoff Distance	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Over Slot
Comment
Comment:
Comment:

10:42:03	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-14	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	15 degrees
ICM Pendant Filename	PGM1	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment:
Comment:
Comment:
Comment:

APPENDIX B

BATH IRON WORKS LETTER REPORT

TRIP REPORT

Trip to: Applied Research Laboratory, Penn State University

Date: October 29-30, 1992

By: Paul A. Blomquist, Senior Welding Engineer, Bath Iron Works Corporation

Purpose: Witness robotic cutting of steel shapes using 1.8 KW YAG laser

Background:

AM has been exploring the applicability of fiber-optic coupled YAG laser systems to shipbuilding. Of great interest is the suitability of this process and equipment to the cutting of standard structural shapes used in ship fabrication. To support this evaluation, BIW provided ARL with scrap pieces of angles, channels and T-bars of typical 50-ksi yield alloy (AH-36), and listings of the complete range of shapes used in current surface ship fabrication. Following a period of development testing, cutting demonstrations were made and video-taped.
Of particular interest was the comparison of the laser system to the PROSHAPS system currently in use at BIW, which uses plasma-arc cutting (PAC) in a similar range of cut geometries. Additionally. comparison of laser-cut surfaces to those produced by manual oxy-fuel cutting (OFC) was made.

Results of testing:

Cutting parameters and details of process operation are reported elsewhere by Eric Whitney of ARL. In general, however, it must be remembered that in all development work, existing installed equipment does not always initially perform a new task as well as more traditional equipment built for the purpose of the given task. This was mainfestly the situation here: the head and focusing optics of the 1.8 KW YAG unit were simply too large to gain good access to the inside comers of Tee-Bars and I-Beams. Even with this limitation, by carefully controlling the travel speeds, and working at the maximum focus distance practical, and adequate cut could be made with the existing hardware. Obviously, these parts could be modified if the potential shown in other, less constricted areas demonstrated that further development work was warranted.

Cutting speeds up to 40 inches per minute were achieved using this equipment. This is double the speed typically used for most mechanized OFC applications, and consistent with the current speeds used in PAC systems. As with PAC, laser cutting speeds will vary with material thickness; more development work is needed to define the upper limits of laser processing speed, and the potential beneficial effects on cut edges and oveall product quality which higer speeds could yield.

Comparison cuts were made using the 1.5 KW pulsed $C0_2$ laser. Again, the optics and head configuration prevented a direct comparison of all the cut geometries that PROSHAPS or manual cutting can produce. Nonetheless, the cut surface smoothness and narrow kerfs showed that potential exists for further development. The main conclusion of the comparison between these devices (the YAG and the CO_2 systems) is that development of special-purpose optics and gas nozzle/orifice systems should be done so that the laser systems can perform at an optimum level in any future testing.

There was an obvious reduction in the levels of smoke produced by the- laser cutting process compared to those experienced with OFC and PAC. This could have significant impac on compliance to standards for air quality, especially since these standards are becoming geometrically more stringent. Although carbon steels were used for this test program. the benefits of laser cutting would show even greater value in the cutting of chrome-nickel alloys, which are finding greater use in ship systems were longer and more reliable service is demandec Furthermore, many copper systems are being replaced with CRES alloys in which the productio of hexavalent chromium fines by the cutting process could be a problem.

All laser-cut kerfs were significantly narrower than those produced by OFC or PAC. Certainly, all the cut surfaces were as good or better than those produced by manual OFC, and, while slightly rougher than those produced by plasma cutting, showed significantly less bevellir on either side of the kerf. This could be especially beneficial in the mass-processing of small parts cut from long, standard length shapes, since there is greater potential for producing “net-shape” parts using both edges of one cut. This is a favorable contrast with PROSHAPS. where the plasma process requires that a certain amount of material be scrapped between cuts sc that a reasonably square edge will be made on each part.

In general, the potential for laser cutting using such a fiber optic system was shown. As stated above, the potential for higher speed, good cut quality, superior edge squareness, and low levels of fume emission was demonstrated. The development of suitable optics and nozzles will allow a more thorough evaluation of the economics of using this process, and should be undertaken as quickly as possible.

Paul A. Blomquist

10:46:47 PROCESS.BAS 10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility

CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-15	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	120 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CU'ITING Speed (ipm):	40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	15 degrees
ICM Pendant Filename	P G M 1	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Over Slot
Comment:
Comment:
Comment:

10:53:18 PROCESS.BAS 10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility

CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-16	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1600	Specimen typx	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename	PGM1	Standoff Distance	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Table
Comment:
Comment:
Comment

11:16:37	PROCESS.BAS	10-29-1992
	ARL/MSRF Nd:YAG Laser Processing Facility	
	CW Nd:YAG Laser/Robotic CUTTING	

Run ID	Specimen Code		
-18	carbon steel	Assist Gas:	air
		Gas pressure (psig):	270 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1690	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	20 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename	PGM1	Standoff Distance	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment:
Comment:
Comment:
Comment:

11:22:55	PROCESS.BAS	10-29-1992
	ARL/MSRF Nd:YAG Laser Processing Facility	
	CW Nd:YAG Laser/Robotic CUTTING	

Run ID	Specimen Code		
-19	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle	15 degrees
ICM Pendant Filename	PGM1	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment:
Comment:
Comment:
Comment

11:37:45 PROCESS.BAS 10-29-199

ARL/MSRF Nd:YAG Laser Processing Facility

CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-20	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename:	PGM1	Standoff Distance	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment:

11:43:59 PROCESS.BAS 10-29-199

ARL/MSRF Nd:YAG Laser Processing Facility

CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-21	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1680	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Fllename	CUTTING	Plate to Head Angle	15 degrees
ICM Pendant Filename:	PGM1	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):.
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment:

13:14:40	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-22	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh
Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	15 degrees
ICM Pendant Filename:	PGM1	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment:

13:19:12	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-23	carbon steel	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh
Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1670	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename	CUITING	Plate to Head Angle:	15 degrees
ICM Pendant Filename	PGM1	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment
Comment:
Comment:

14:07:12 PROCESS.BAS 10-29-199

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-24	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (pig):	180 Cfh
Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1680	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle	15 degrees
ICM Pendant Filename	PGM8	Standoff Distance	. 2 5 0

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment:

14:13:55 PROCESS.BAS 10-29-199

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-25	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh
Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1650	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename	PGM8	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Cornment:

14:33:57	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-26	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1630	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	15 degrees
ICM Pendant Filename	PGM8	Standoff Distance	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment

14:44:50	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-27	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename:	PGM8	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment:

15:00:01	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-28	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename:	PGM8	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (sw):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment:

15:07:33	PROCESS.BAS	10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-29	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (psig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1650	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename	PGM8	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment: Off Axis 90 Degrees
Comment:
Comment:
Comment:

15:38:36 PROCESS.BAS 10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-30	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (pig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1650	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename:	PGM8	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Time (see):
Comment Off Axis 90 Degrees
Comment:
Comment:
Comment:

15:43:25 PROCESS.BAS 10-29-1992

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
-31	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (pig):	180 Cfh

Laser Power Setting (Watts):	1800		
Laser Power Reading (Watts):	1700	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.250
A132 Robot Function	PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename	PGM8	Standoff Distance	.250

Additional Information & Post-test Comments

Weld Time (sec):
Comment: Off Axis 90 Degrees
Comment:
Comment
Comment:

15:50:02	PROCESS.BAS	10-29-1992

ARIJMSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code			
-32	T SECTION		Assist Gas:	OXYGEN
			Gas pressure (psig):	180 Cfh
Laser Power Setting (Watts):		1800		
Laser Power Reading (Watts):		1700	Specimen type	carbon steel
Water Resistivity (Megohms):		5.0	Spec. thickness:	.250
A132 Robot Function:		PGM6	CUTTING Speed (ipm):	40/20/40 ipm
A132 Robot Filename		CUTTING	Plate to Head Angle:	15 degrees
ICM Pendant Filename		PGM8	Standoff Distance	.250

Additional Information & Post-test Comments

Weld Time (see):
Commenfi Off Axis 90 Degrees
Comment:
Comment:
Comment:

16:02:01	PROCESS.BAS	10-29-1992

ARIJMSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUITING

Run ID	Specimen Code			
-33	T SECTION		Assist Gas:	OXYGEN
			Gas pressure (psig):	180 Cfh
Laser Power Setting (Watts):		1800		
Laser Power Reading (Watts):		1650	Specimen type	carbon steel
Water Resistivity (Megohms):		5.0	Spec. thickness:	.250
A132 Robot Function:		PGM6	CU1'TING Speed (ipm):	40/20/40 ipm
A132 Robot Filename:		CU'ITING	Plate to Head Angle:	15 degrees
ICM Pendant Filename		PGM8	Standoff Distance:	.250

Additional Information & Post-test Comments

Weld Tme (see):
Commenfi Off Axis 90 Degrees
Comment
Comment:
Comment:

10:27:29	ROBOLUM.BAS ARL/MSRF Nd:YAG Laser Processing Facility PULSED Nd:YAG Laser/Robotic CUTTING	11-12-1992

Run ID	Specimen Code			
	T SECTION		Assist Gas:	OXYGEN
			Gas pressure (psig):	60 PSI

Laser Power Setting (Watts):	380		
Laser Power Reading (Watts):	380	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.045
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	30 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	8 degrees
ICM Pendant Filename:	PGM1	Standoff Distance:	CLOSE

Additional Information & Post-test Comments

Weld Time (see):
Comment: not through
Comment:
Comment:
Comment:

10:34:29	ROBOLUM.BAS ARL/MSRF Nd:YAG Laser Processing Facility PULSED Nd:YAG Laser/Robotic CUTTING	11-12-1992

Run ID	Specimen Code			
2	T SECTION		Assist Gas:	OXYGEN
			Gas pressure (psig):	80 PSI

Laser Power Setting (Watts):	380		
Laser Power Reading (Watts):	380	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.045
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	30 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle	8 degrees
ICM Pendant Filename:	PGM1	Standoff Distance:	CLOSE

Additional Information & Post-test Comments

Weld Time (see):
Comment: not through
Comment:
Comment:
Comment:

10:52:57	ROBOLUM.BAS	11-12-1992

ARL/MSRF Nd:YAG Laser Processing Facility
PULSED Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
3	T SECTION	Assist Gas:	OXYGEN
		Gas pressure (pig):	80 PSI

Laser Power Setting (Watts):	380		
Laser Power Reading (Watts):	380	Specimen type:	carbon steel
Water Resistivity (Megohms):	5.0	Spec. thickness:	.045
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	30 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle:	8 degrees
ICM Pendant Filename:	PGM1	Standoff Distance	CLOSE

Additional Information & Post-test Comments

Weld Time (see):
Comment:
Comment:
Comment:
Comment:

11:07:22	ROBOLUM.BAS	11-12-199

ARL/MSRF Nd:YAG Laser Processing Facility
PULSED Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
5	T SECTION	Assist Gas:	p
		Gas pressure (psig):	80 PSI

Laser Power Setting (Watts):	380		
Laser Power Reading (Watts):	380	Specimen type:	carbon steel
Water Resistivity (Megohms):	540	Spec. thickness:	.045
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	4 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle:	8 degrees
ICM Pendant Filename:	PGM1	Standoff Distancti	CLOSE

Additional Information & Post-test Comments

Weld Time (see):
Comment:
Comment:
Comment:
Comment:

11:13:12	ROBOLUM.BAS	11-12-1992

ARL/MSRF Nd:YAG Laser Processing Facility
PULSED Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
6	T SECTION	Assist Gas:	p
		Gas pressure (psig):	80 PSI

Laser Power Setting (Watts):	380		
Laser Power Reading (Watts):	380	Specimen type	carbon steel
Water Resistivity (Megohms):	5.0	SUEZ. thickness:	.045
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	6 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	8 degrees
ICM Pendant Filename:	PGM1	Standoff Distance:	CLOSE

Additional Information & Post-test Comments

Weld Time (see):
Comment:
Comment:
Comment:
Comment:

10:1445	PROCESS.BAS	02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-1	SHEET	Assist Gas:	OXYGEN
		Gas pressure (pig):	140 PSI

Laser Power Setting (Watts):	1070		
Laser Power Reading (Watts):	1000	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
A132 Robot Function	LCLAD	CUTTING Speed (ipm):	80 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle	o
ICM Pendant Filename	PGM1	Standoff Distance	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: 140 PSI 150 CFH
Comment: ROUGH CUT
Comment:
Comment

10:22:37	PROCESS.BAS	02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-2	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	1080		
Laser Power Reading (Watts):	1000	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. Wlckness:	.090
A132 Robot Function:-	LCLAD	CUTTING Speed (ipm):	120 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: 140 PSI 150 CFH
Comment: BETTER INCREASES IN DROSS
Comment:
Comment:

10:28:05	PROCESS.BAS	02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-3	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	1080		
Laser Power Reading (Watts):	1000	Specimen type	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
A132 Robot Function	LCLAD	CUTTING Speed (ipm):	100 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	0
ICM Pendant Filename	PGM1	Standoff Distance	.025

Additional Information & Post-test Comments

Weld Time (sw):
Comment: 140 PSI 150 CFH
Comment: STILL DROSSY
Comment:
Comment:

10:42:55 PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-4	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2010		
Laser Power Reading (Watts):	2000	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
A132 Robot Function	LCLAD	CUTTING Speed (ipm):	100 ipm
A132 Robot Filenamti	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: LESS DROSS
Comment:
Comment:

10:47:46 PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-5	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2400		
Laser Power Reading (Watts):	2400	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
A132 Robot Function	LCLAD	CUTTING Speed (ipm):	100 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: 140 PSI 150 CFH
Comment: NOT AS GOOD AS #4
Comment:
Comment

10:53:49	PROCESS.BAS	02-01-199:

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-6	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2010		
Laser Power Reading (Watts):	2000	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	100 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: REPEAT OF #4
Comment:
Comment:

10:59:55	PROCESS.BAS	02-01-199:

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-7	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2010		
Laser Power Reading (Watts):	2000	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	200 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: DROSS BRIDGE
Comment:
Comment:

11:06:48 PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-8	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2400		
Laser Power Reading (Watts):	2400	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	200 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: BETTER THAN #7
Comment:
Comment:

11:19:15 PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-9	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2400		
Laser Power Reading (Watts):	2400	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.090
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	60 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: NICE
Comment:
Comment:

11:24:00 PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-10	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI
Laser Power Setting (Watts):	2400		
Laser Power Reading (Watts):	2400	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.250
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	80 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: ROUGHER #9
Comment:
Comment:

13:36:45 PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-11	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI
Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2440	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.250
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	100 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: DROSS BRIDGE
Comment:
Comment:

13:41:59	PROCESS.BAS ARL/MSRF Nd:YAG Laser Processing Facility CW Nd:YAG Laser/Robotic CUTTING	02-01-1993

Run ID	Specimen Code		
2-1-93-12	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2430	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.250
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: RAGGY CUT
Comment:
Comment:

13:50:50	PROCESS.BAS ARL/MSRF Nd:YAG Laser Processing Facility CW Nd:YAG Laser/Robotic CUTTING	02-01-1993

Run ID	Specimen Code		
2-1-93-13	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2435	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.250
AI32 Robot Function:	LCLAD	CUTTING Speed (ipm):	60 ipm
AI32 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (sec):
Comment: 140 PSI 150 CFH
Comment: RAGGY CUT OUT OF FOCUS
Comment:
Comment:

13:56:35 PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility

CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-14	SHEET	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2430	Specimen type	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	60 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: 140 PSI 150 CFH
Comment: RAGGED CUT
Comment:
Comment:

PROCESS.BAS 02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility

CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-15	SHEET	Assist Gas:	OXYGEN
		Gas pressure (pig):	140 PSI

Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2400	Specimen type:	carbon steel
Water Resistivity (Megohms):	2.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	80 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: 140 PSI 150 CFH
Commen: NICE
Commen:
Comment:

15:34:20	PROCESS.BAS	02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-16	T-SEC	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI
Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2400	Specimen typt:	STRUCT
Water Resistivity (Megohms):	2.0	Spec. thickness:	.375
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	40 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM1	Standoff Distance	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: 140 PSI 150 CFH
Comment: NICE
Comment:
Comment:

15:45:08	PROCESS.BAS	02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-17	T-SEC	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI
Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2420	Specimen type:	STRUCT
Water Resistivity (Megohms):	2.0	Spec. thickness:	.250
A132 Robot Function:	LCLAD	CUTTING Speed (ipm):	80 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	0
ICM Pendant Filename:	PGM1	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (see):
Commen: 140 PSI 150 CFH
Comment: NICE
Comment:
Comment:

16:24:04	PROCESS.BAS	02-01-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-1-93-18	T-SEC	Assist Gas:	OXYGEN
		Gas pressure (psig):	140 PSI

Laser Power Setting (Watts):	2250		
Laser Power Reading (Watts):	2420	Specimen type:	STRUCT
Water Resistivity (Megohms):	2.0	Spec. thickness:	.375/.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40 iprn/80 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename	PGM8	Standoff Distance	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment:
Comment:
Comment:
Comment:

09:07:50	PROCESS.BAS	02-02-1993

ARL/MSRF Nd:YAG Laser Processing Facility
CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-2-93-1	T-SEC	Assist Gas:	OXYGEN
		Gas pressure (pig):	140/150 PSI

Laser Power Setting (Watts):	2310		
Laser Power Reading (Watts):	2320	Specimen type:	STRUCT
Water Resistivity (Megohms):	2.0	Spec. thickness:	.375/.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40 ipm/80 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename:	PGM8	Standoff Distance	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: VERY NICE
Comment:
Comment:
Comment:

09:25:03 PROCESS.BAS 02-02-1993

ARL/MSRF Nd:YAG Laser Processing Facility

CW Nd:YAG Laser/Robotic CUTTING

Run ID	Specimen Code		
2-2-93-2	T-SEC	Assist Gas:	OXYGEN
		Gas pressure (psig):	140/150 psi
Laser Power Setting (Watts):	2310		
Laser Power Reading (Watts):	2370	Specimen type:	STRUCT
Water Resistivity (Megohms):	2.0	Spec. thickness:	.375/.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40 ipm/80 ipm
A132 Robot Filename:	CUTTING	Plate to Head Angle	0
ICM Pendant Filename:	PGM8	Standoff Distance:	.025

Additional Information & Post-test Comments

Weld Time (see):
Comment: VIDEO SHOT #1 VERY NICE
Comment:
Commen:
Comment:

09:42:44 PROCESS.BAS 02-02-1993

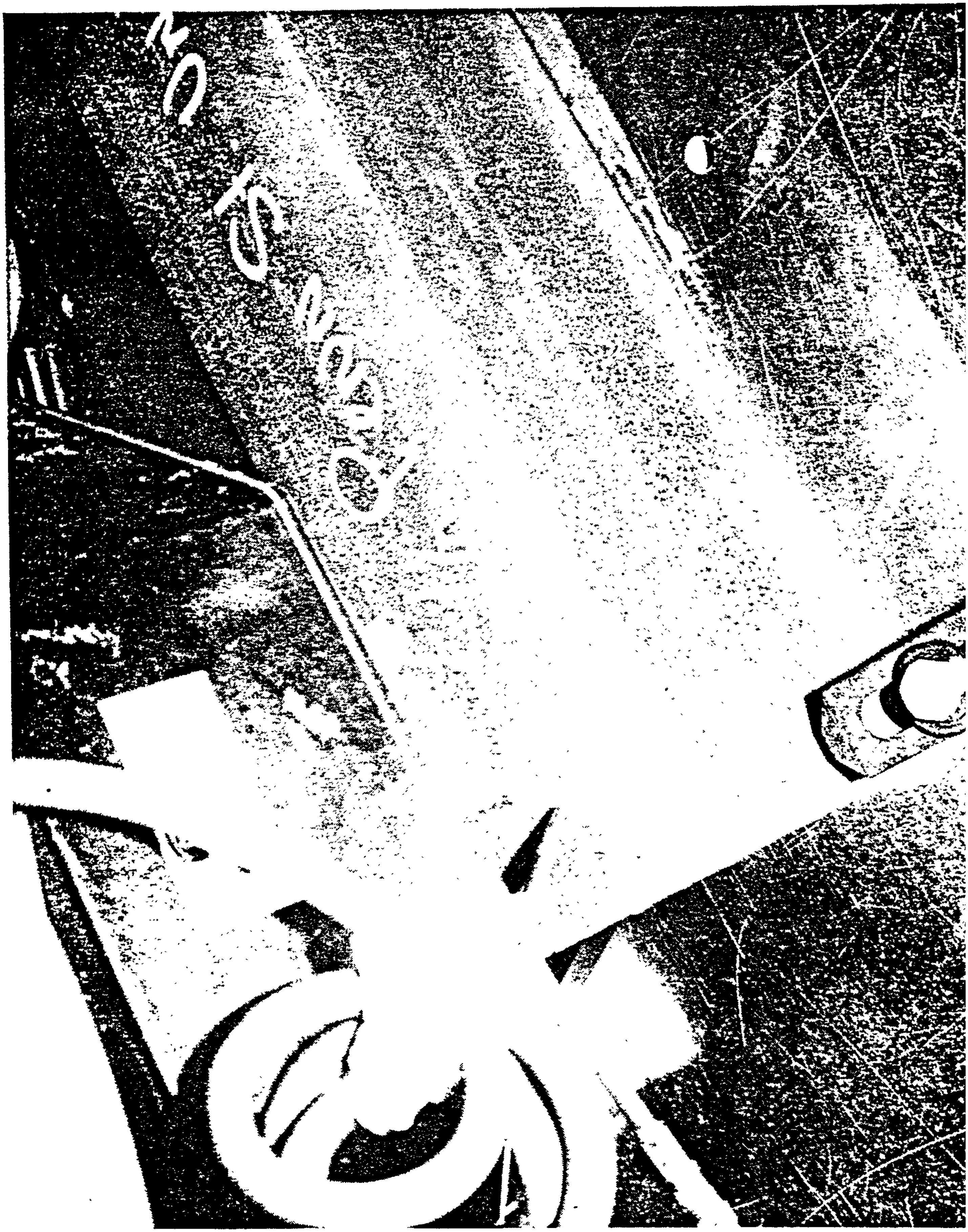
ARL/MSRF Nd:YAG Laser Processing Facility

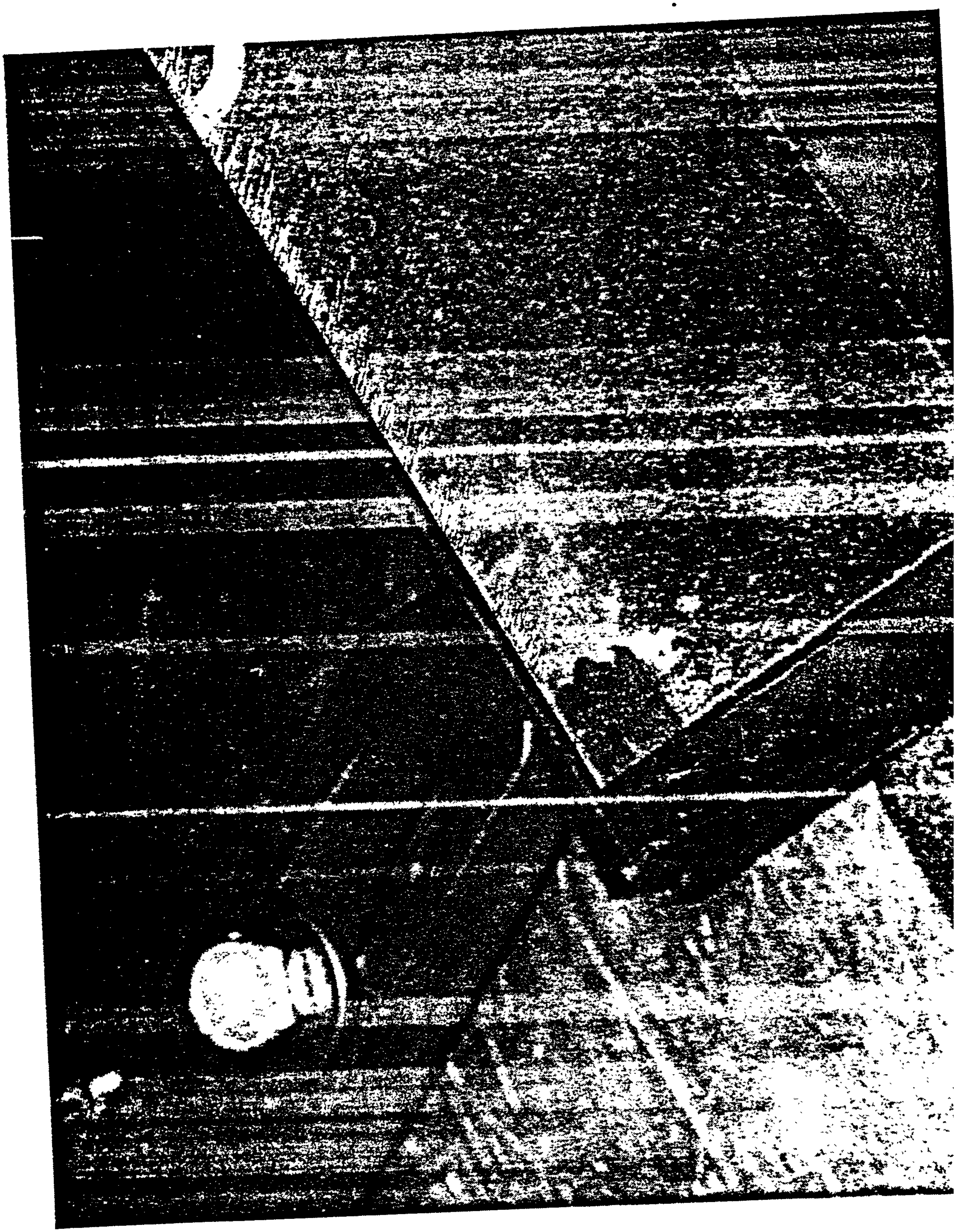
CW Nd:YAG Laser/Robotic CUTTING

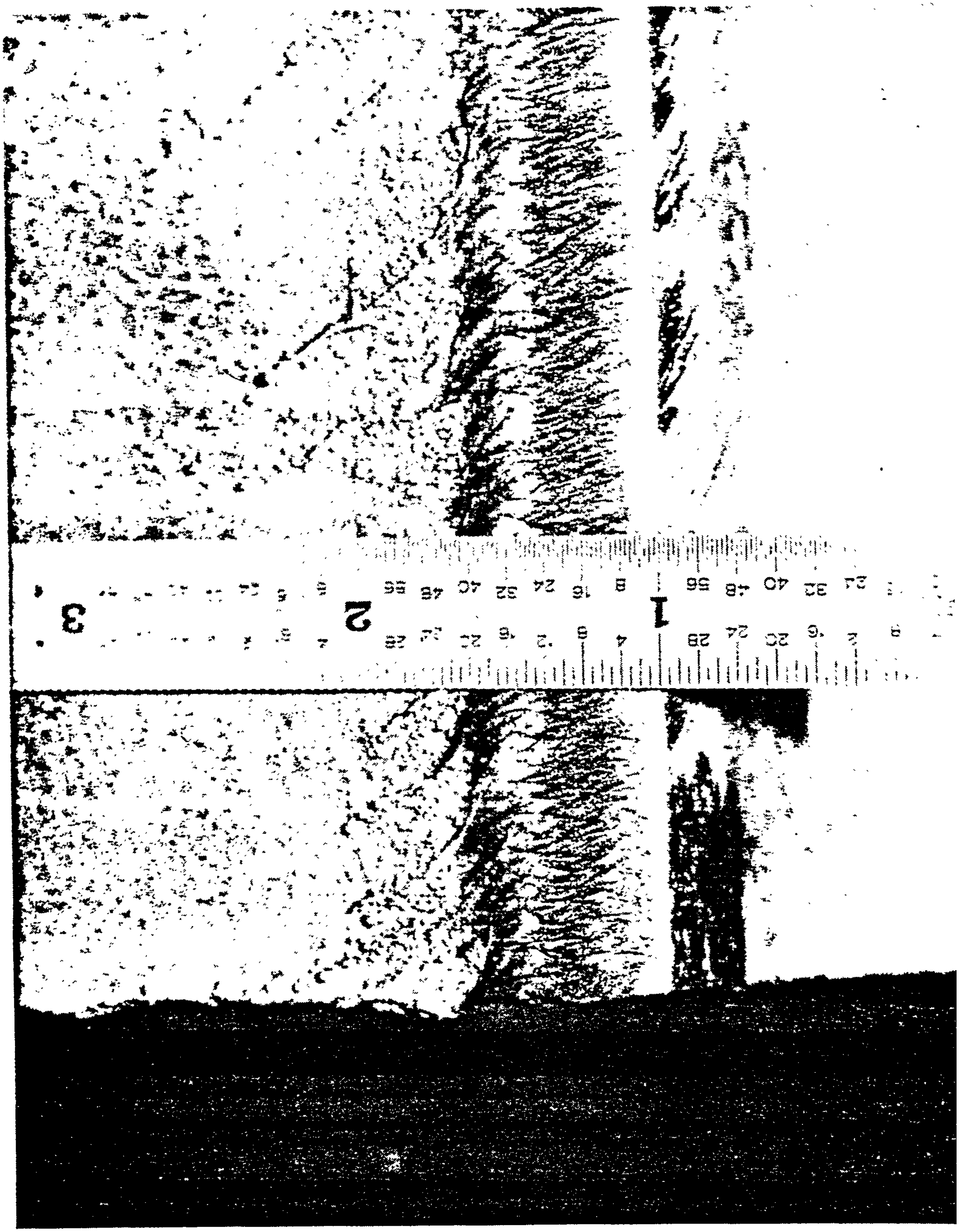
Run ID	Specimen Code		
2-2-93-3	T-SEC	Assist Gas:	OXYGEN
		Gas pressure (psig):	140/150 PSI
Laser Power Setting (Watts):	2310		
Laser Power Reading (Watts):	2460	Specimen type:	STRUCT
Water Resistivity (Megohms):	2.0	Spec. thickness:	.375/.250
A132 Robot Function:	PGM6	CUTTING Speed (ipm):	40 ipm/80 ipm
A132 Robot Filename	CUTTING	Plate to Head Angle:	0
ICM Pendant Filename	PGM8	Standoff Distance	.025

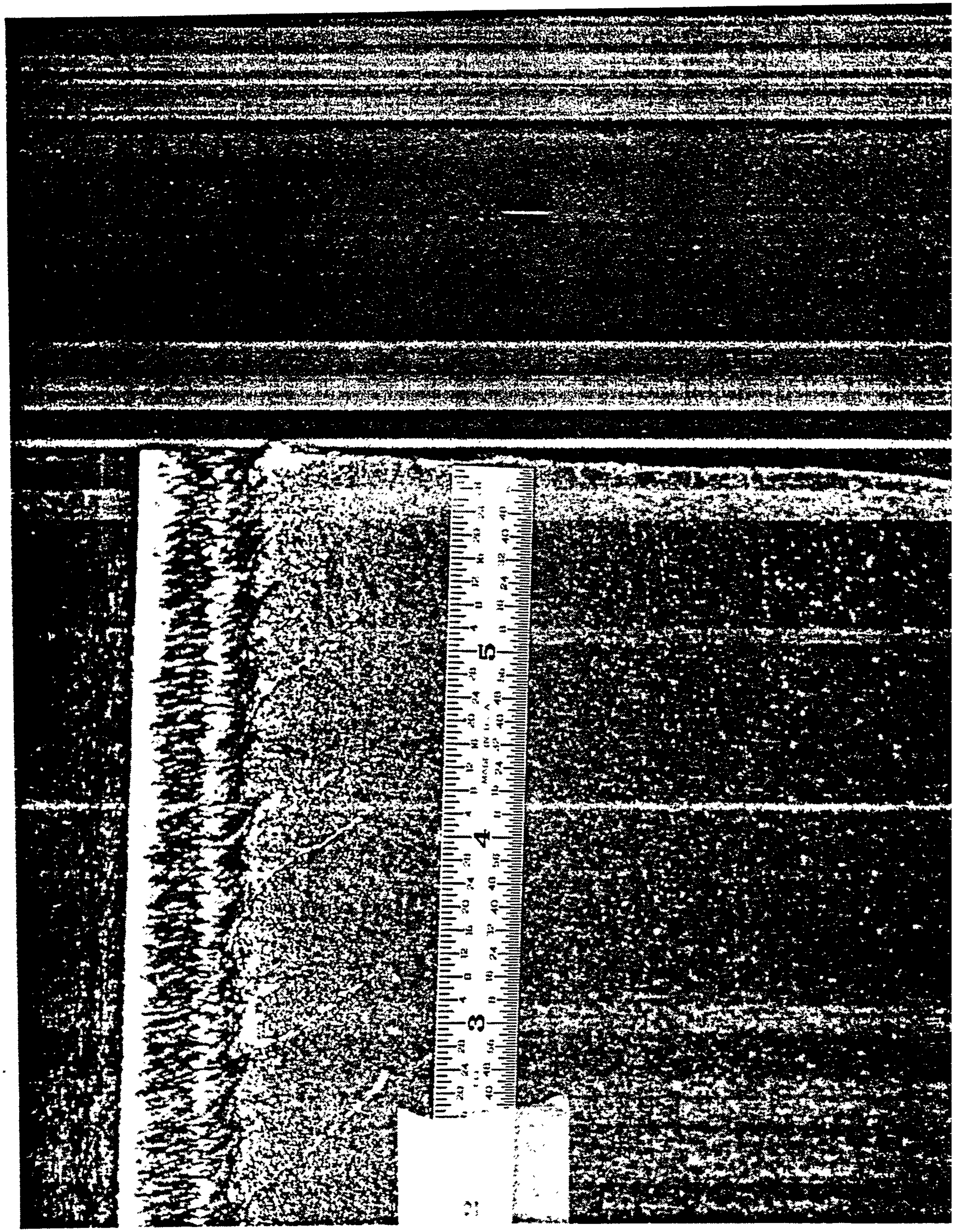
Additional Information & Post-test Comments

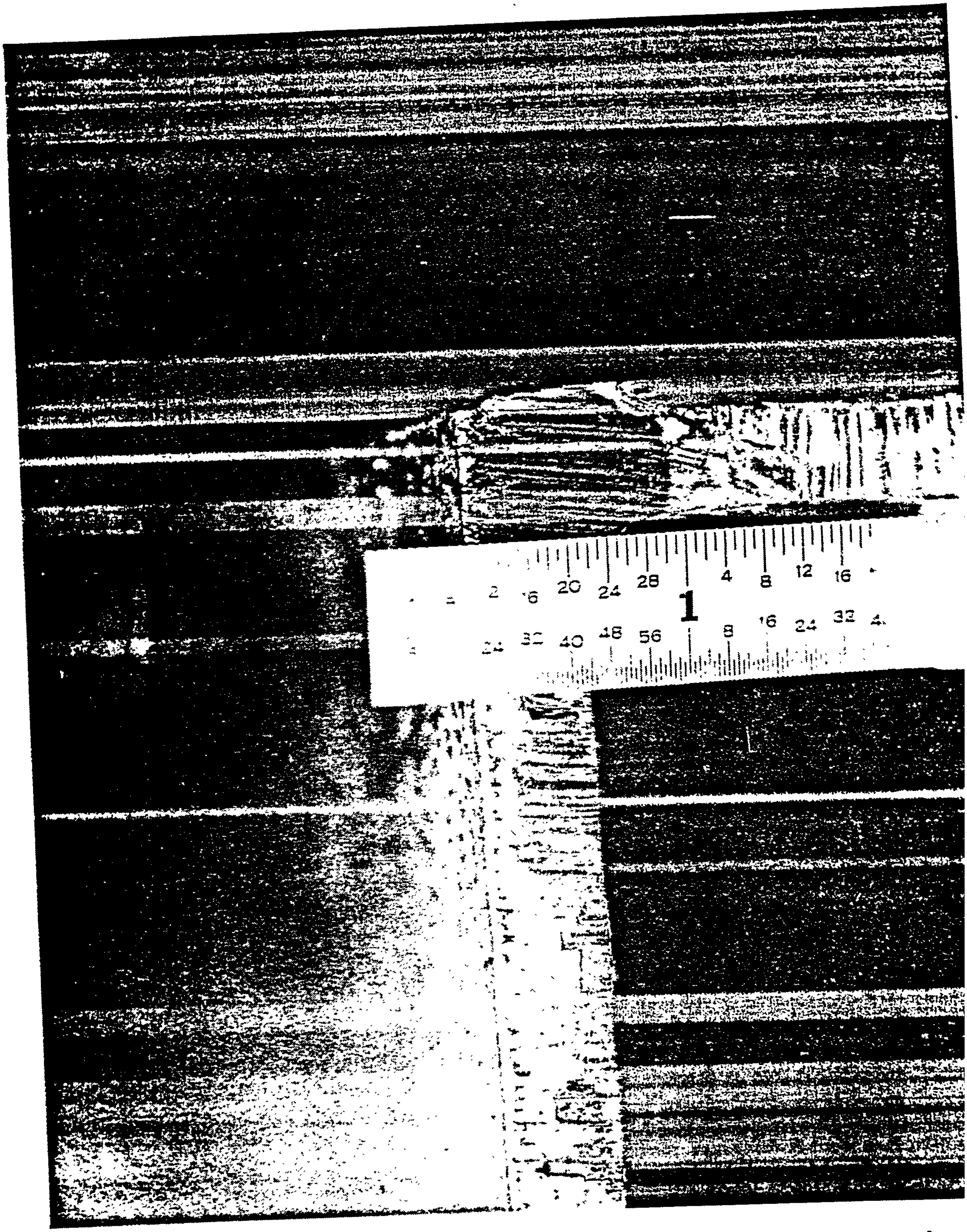
Weld Time (see):
Commen: VIDEO #2 VERY NICE
Cornmen:
Commen:
Comment:

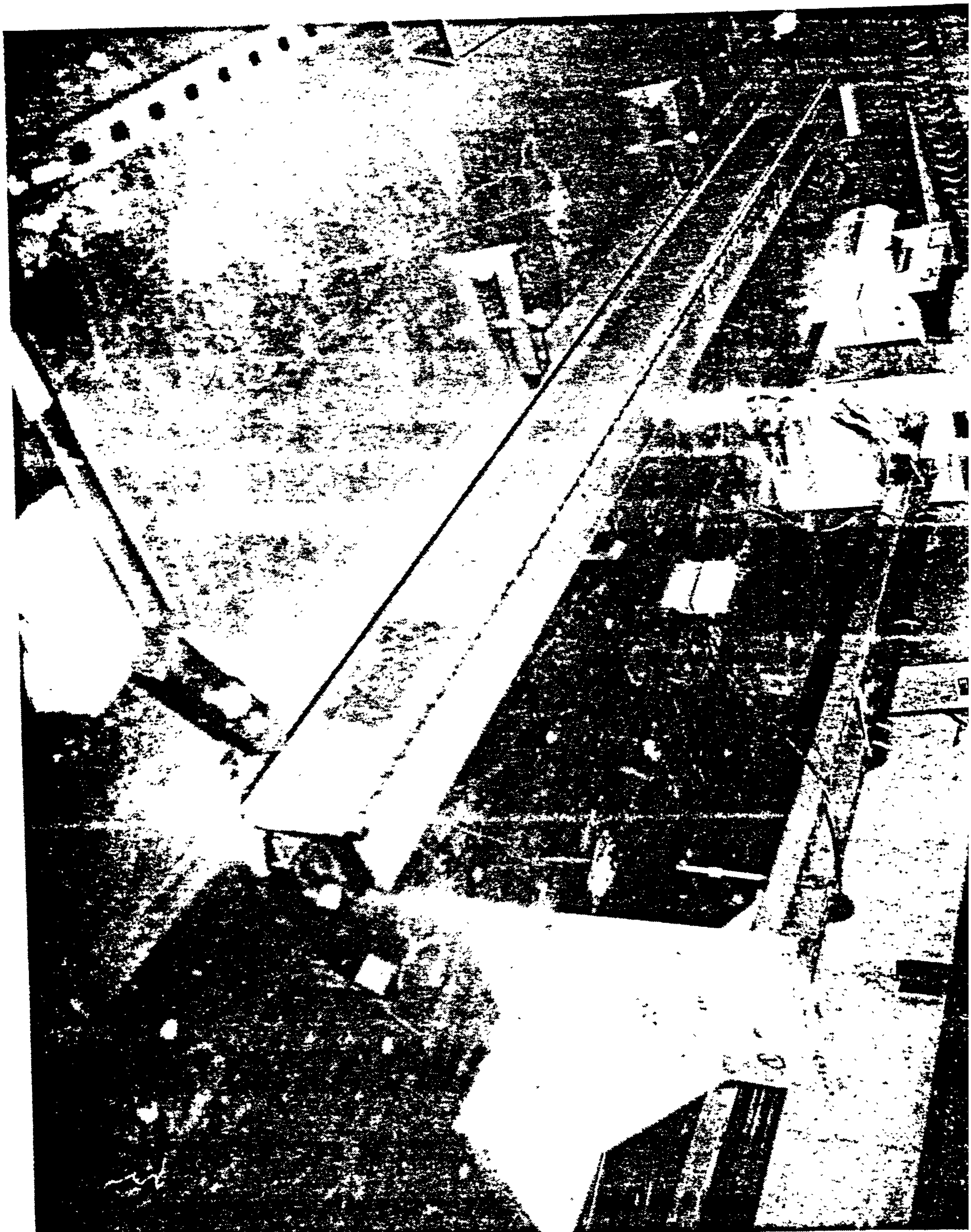


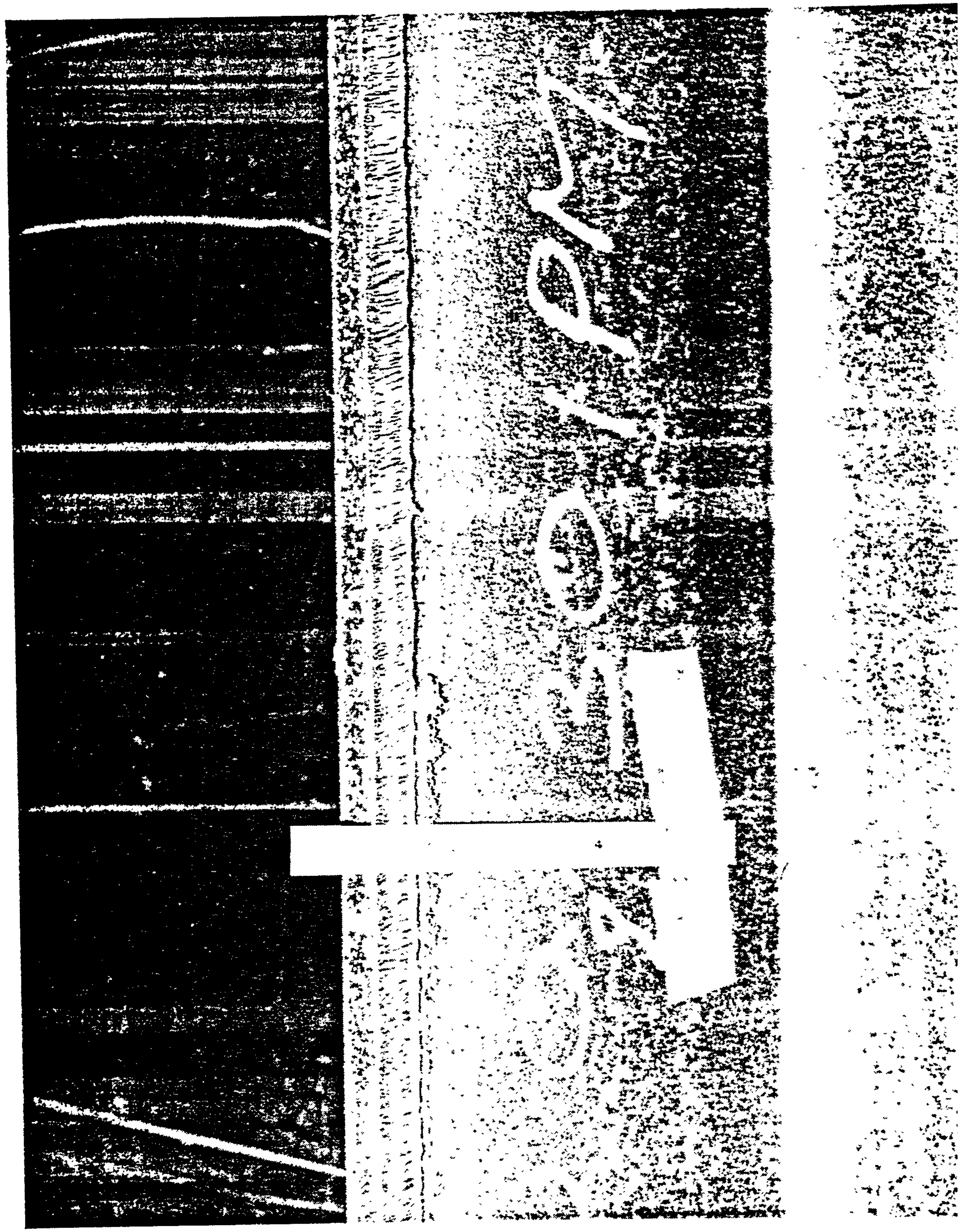


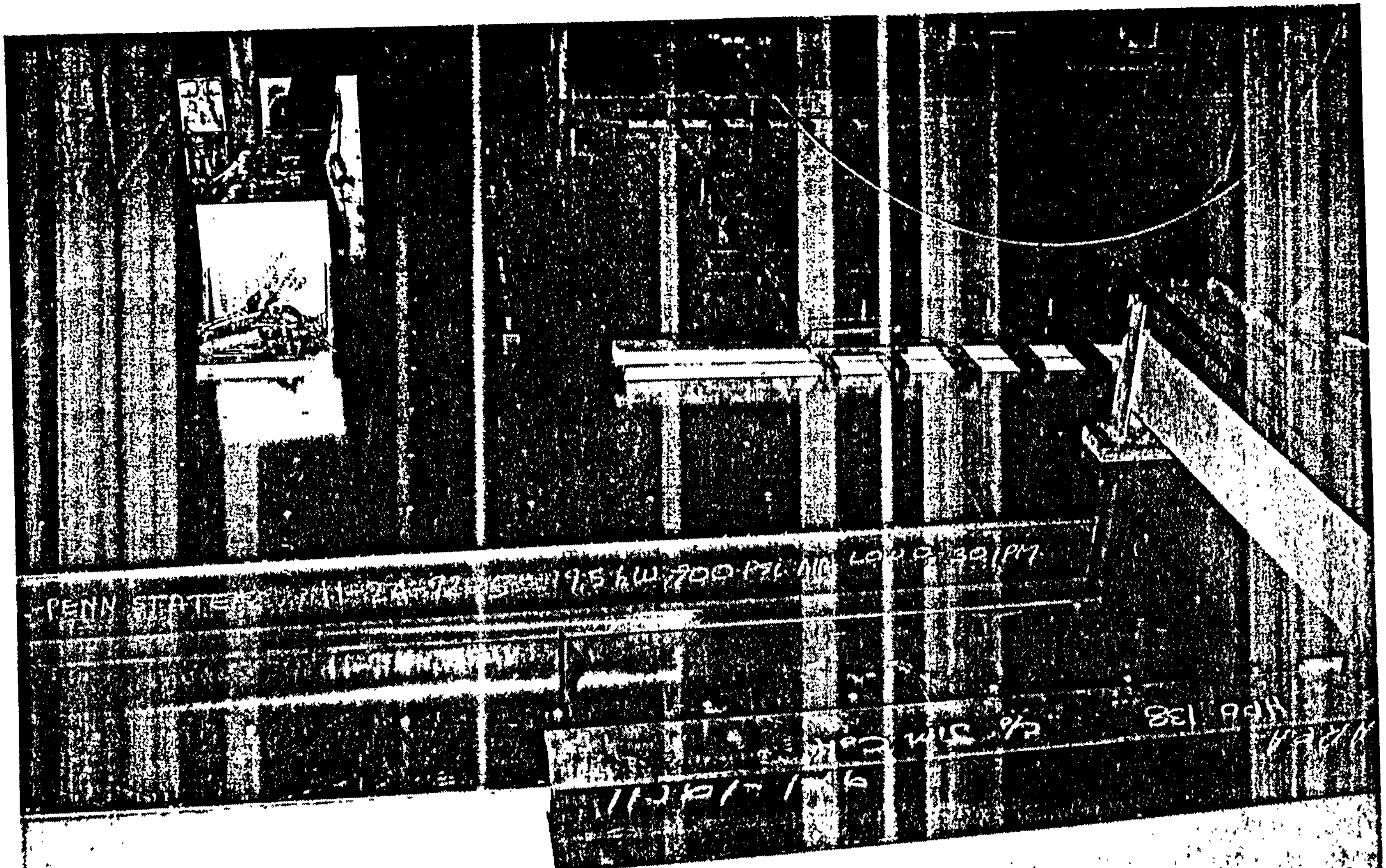








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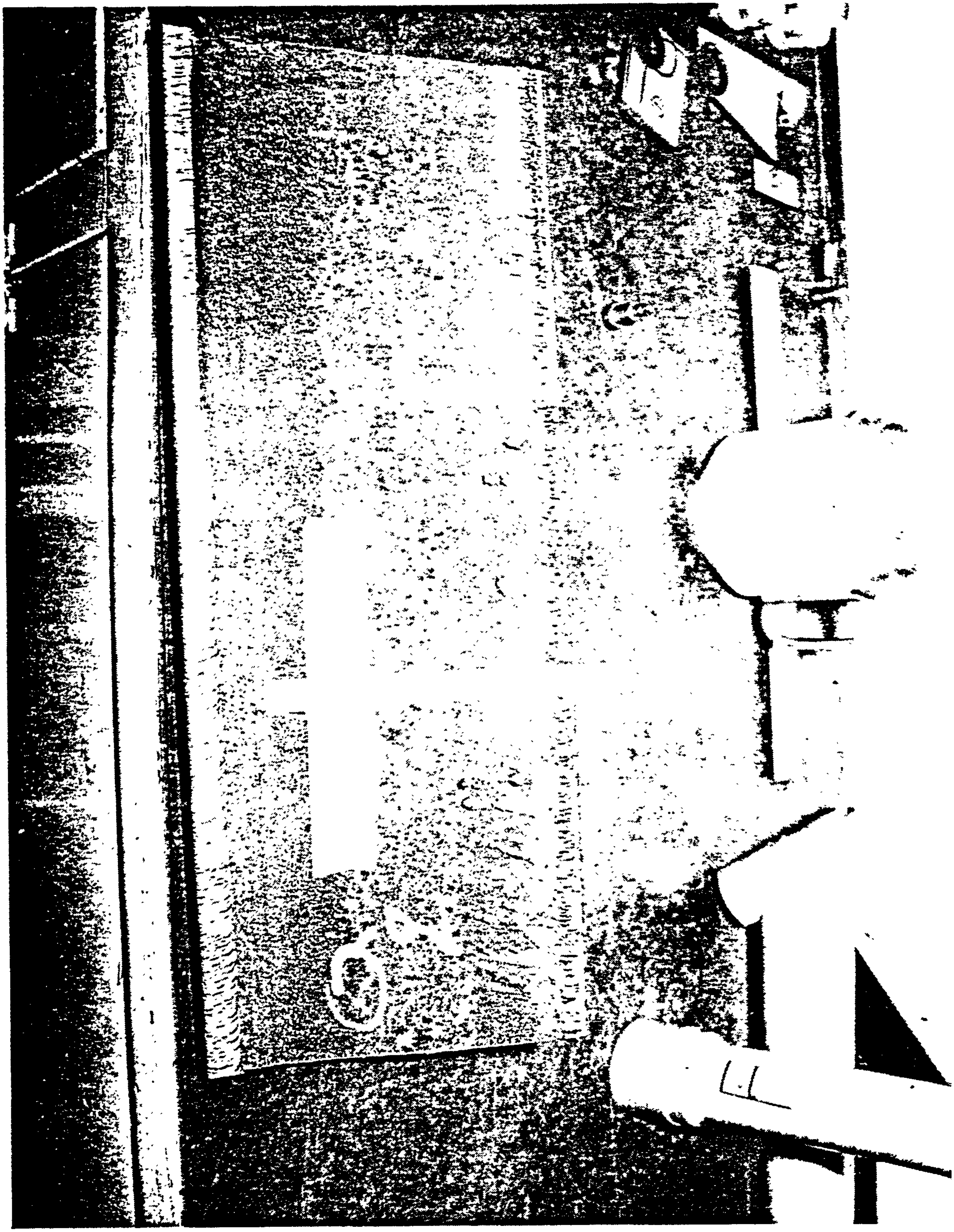

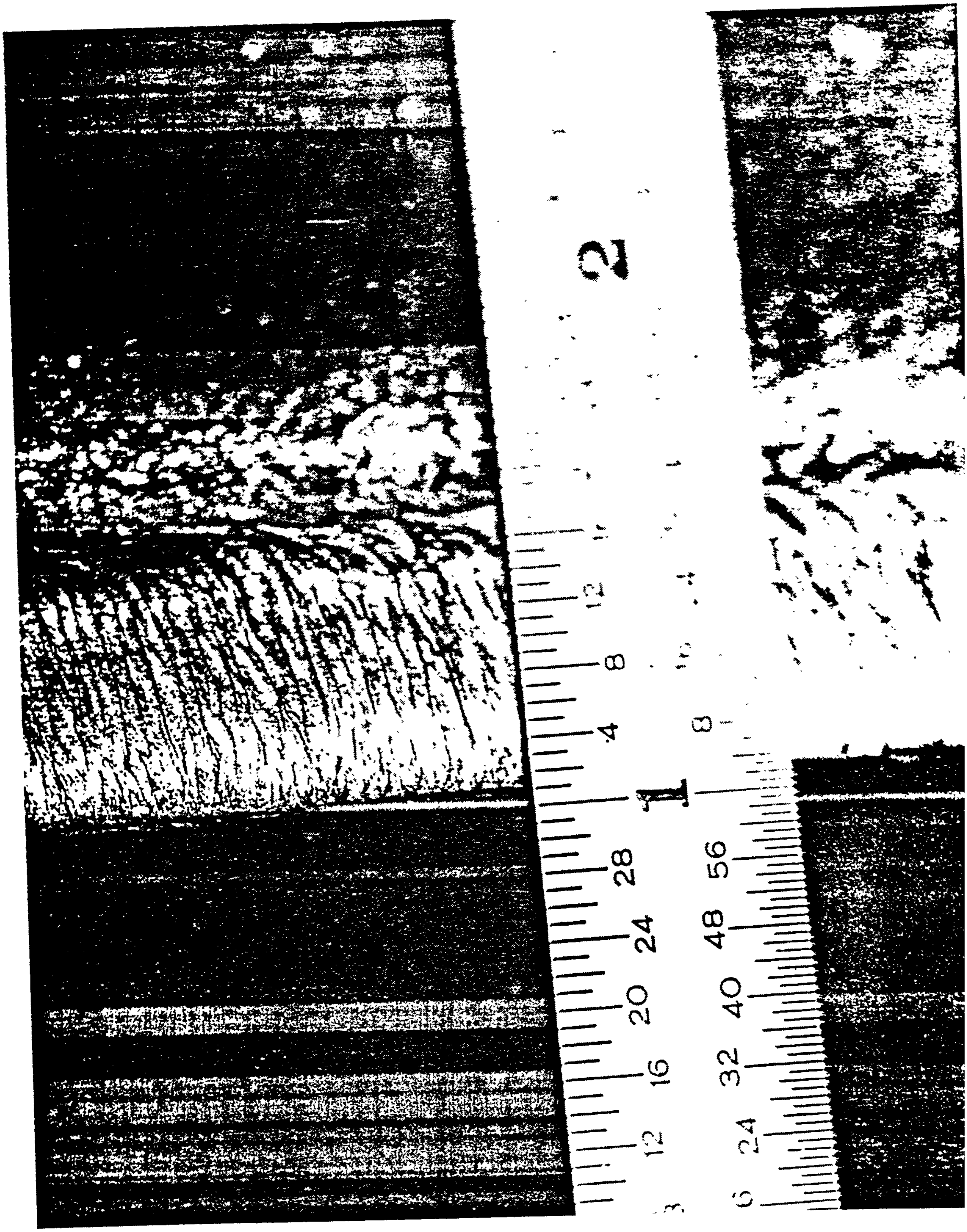

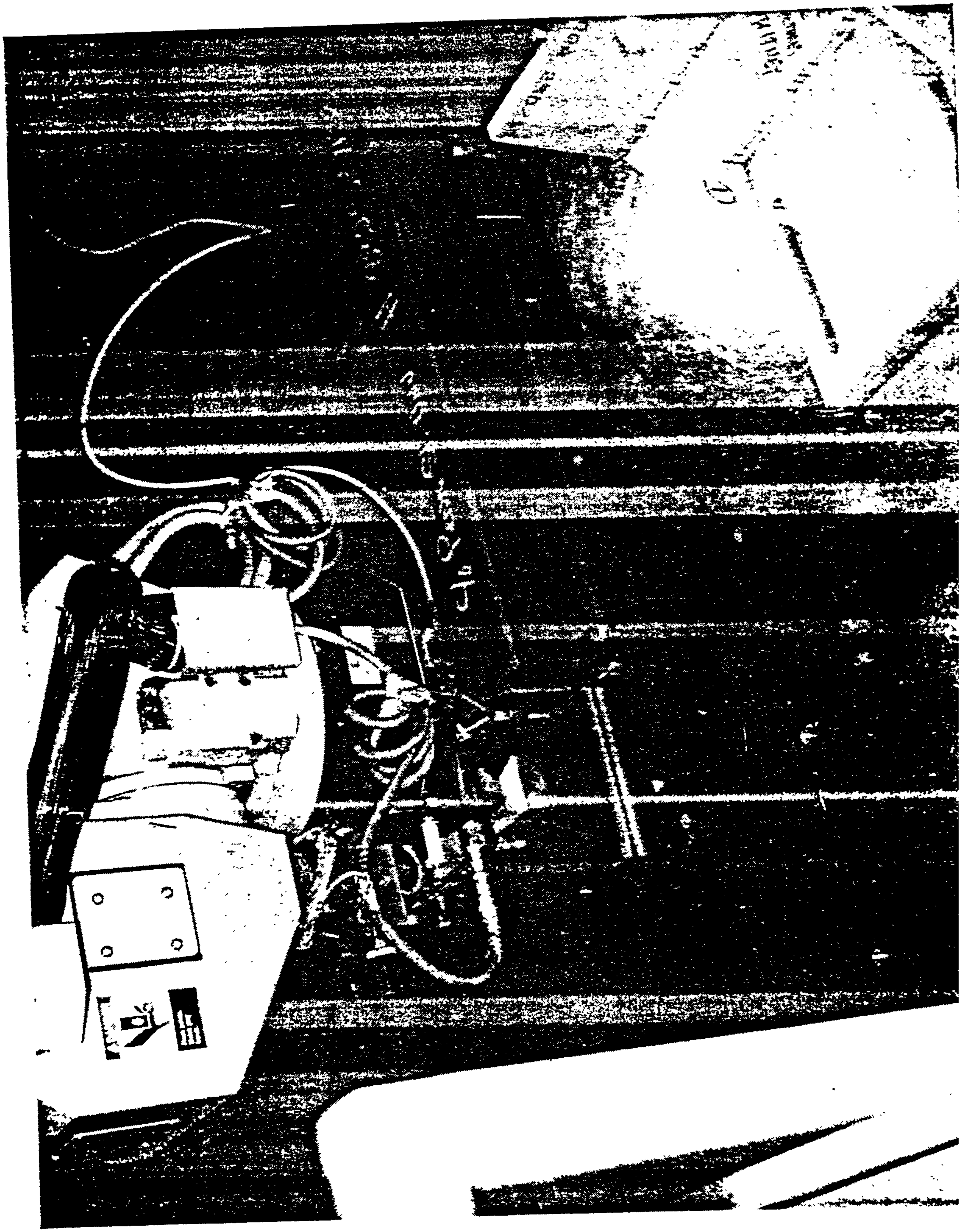

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